Revegetation of Campgrounds after Mortality of Pines due to Bark Beetles in the Rocky Mountain Region

CONTENTS

Figure 1. Mortality of nearly all mature lodgepole pine from attack by mountain pine beetle in a campground in Colorado.

INTRODUCTION

An outbreak of mountain pine beetle continues to build and spread in lodgepole and ponderosa pines, damaging a large number of developed campgrounds on the Medicine Bow/Routt, Arapaho/Roosevelt, and White River National Forests. In some stands, mortality of 90% of mature lodgepole pine is expected before the outbreak subsides.

This document supplements the Vegetation Management Planning Guide, and is intended as a resource for land managers faced with high tree mortality in campgrounds (Figure 1).

FOREST MANAGEMENT

Many factors need to be considered with campground revegetation. The forest surrounding a campground is important to consider because of the influence from large scale disturbances including fire and insect outbreaks. Active management of the forested acres surrounding the campground provides opportunities to limit fuels build-up and the spread of diseases into the campground vegetation. Thinned forests and forests with diversity in species and structure tend to be more resilient to disturbances.

Soil texture, available moisture, and frost patterns determine which species will thrive. Different species have different susceptibilities to disturbance

agents, including insects, disease, camper abuse, fire and wind. Soil compaction restricts root growth of all plant species, and can predispose established trees to root disease.

IMPORTANT INSECT AND DISEASE AGENTS

The most important insect and disease agents for pine forests are generally dwarf mistletoes and bark beetles.

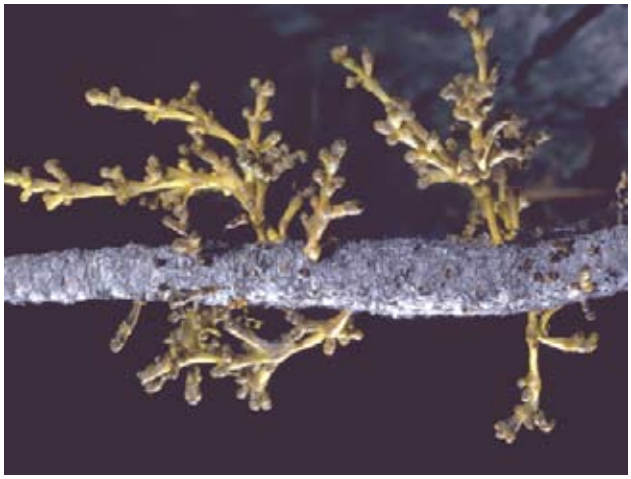

Figure 2. Aerial shoots of dwarf mistletoe and swelling on branch of lodgepole pine (photo source unknown).

Dwarf Mistletoes

Dwarf mistletoes are significant disease agents of pines and Douglas-fir in the Rocky Mountain Region. Tree vigor and longevity are inversely proportional to the amount of dwarf mistletoe infection. Small trees infected with dwarf mistletoe do not grow into large trees. Dwarf mistletoes tend to be host-specific; for example, lodgepole pine dwarf mistletoe will not infect Douglas-fir. Dwarf mistletoe infection intensifies over time, both in the individual tree and in the stand.

Dwarf mistletoes are vascular plants that are obligate parasites of conifers. They depend on the host tree for food and water. The visible portions of the dwarf mistletoe plant are the aerial shoots, which function only for reproduction. Most of the dwarf mistletoe plant is embedded in host tissues (Figure 2).

Dwarf mistletoes spread by sticky seed produced on the aerial shoots. Seeds are explosively discharged, and shoot out to infect other branches. Seeds are sticky and adhere to foliage (or feathers or fur). Animals remove seeds while preening; birds in particular wipe seeds on twigs. Moisture allows the seed to glide down to the base of a needle, germinate, and penetrate thin bark. The time from seed dispersal to seed production by the new plants, generally takes 4-6 years. Tree branches can be infected for some years before exhibiting swelling, aerial shoots, or brooms.

Dwarf mistletoe infection causes swelling and the formation of witches' brooms. Witches' brooms are abnormal, densely branched structures caused by disruption in host physiology. Brooms are nutrient sinks and thrive at the expense of the rest of the tree. Dwarf mistletoe infection reduces growth and weakens the tree, and can predispose the tree to attack by other agents, including root diseases. Heavy dwarf mistletoe infections can cause mortality (Figure 3).

Brooms can act as ladder fuels from ground to crown. Dead trees and dwarf mistletoe brooms, especially in pine, increase stand flammability.

Dwarf Mistletoe Management

In recreation sites, management of dwarf mistletoe considers both the overstory and the understory. First, for infected overstory trees, tree vigor and longevity can be improved by removal of brooms and branches with visible infections in the lower half of the crown, but only for trees with little to no infection in the upper half of the crown. Trees that are infected throughout the crown cannot be helped.

Second, to prevent infection in understory trees, all infected overstory trees of the same species within 50 ft must be removed before understory trees are 3 ft tall or 10 years old. Where the surrounding forest is infected with dwarf mistletoe, a 50 ft buffer kept free of host trees will prevent the spread of dwarf mistletoe into campground trees. Advanced regeneration over 3 ft tall that has been growing under an infected overstory of the same tree species, is most likely infected with dwarf mistletoe (even if aerial shoots are not yet visible). These latent infections often produce aerial shoots when the branches are exposed to more light.

Figure 3. Lodgepole pines heavily infected with dwarf mistletoe, exhibiting brooms, dieback and mortality, in campgrounds in Colorado. (Photos courtesy of Jim Worrall and Jim Blodgett)

Figure 4. Young lodgepole pine with many branches in the lower crown infected by dwarf mistletoe in a campground in Colorado.

Dwarf mistletoe infection in the crown of a small tree will intensify, resulting in the tree becoming heavily infected and stunted, and unable to grow into a large tree. Infected advanced regeneration over 3 ft tall is a source of infection to smaller trees now and in the future (Figure 4). If infected advanced regeneration is desirable for screening purposes, then the new forest (natural regeneration, transplants, or planted seedlings) must be kept at least 30 ft away from them. The size of the host-free buffer depends on the height of infections in the taller trees; a buffer of 30 ft is adequate for infections less than 15 ft high. Remove the infected taller trees or remove any host seedlings/saplings within the buffer before they are 3 ft tall or 10 years old.

For more information on dwarf mistletoes, see Worrall 2008.

Bark Beetles

Bark beetles are important agents of tree mortality. Bark beetles live under tree bark and feed on the phloem and cambium. They have four life stages: egg, larva, pupa, and adult. Adults emit pheromones for locating mates and controlling population densities within host trees. Adults construct galleries where they mate, and females lay eggs. Larvae continue the gallery construction until they are ready to pupate. Conifer bark beetles usually carry stain fungi and other microorganisms into the tree. Top kill and tree mortality result from a combination of girdling by gallery construction and destruction of sapwood vascular function by stain fungi. Trees are often killed in small groups because of the aggregating behavior of beetles in response to pheromones. Root-feeding bark beetles can carry blackstain root disease, a vascular wilt.

Most of the bark beetles have a fairly lengthy flight period during the summer. Many of them are also likely to be around in September and take advantage of host material damaged by fire in that same summer. Early-season fires have a high probability of the trees being colonized that same year.

Bark beetles are generally attracted to trees that are under stress due to root disease, rust cankers, dwarf mistletoe infection, defoliation, fire scorch, drought, crowding, mechanical damage, lightning, or other factors. Douglas-fir beetle and spruce beetle prefer to attack recently windthrown or cut trees, especially material larger than 12-in diameter. Populations build up in the down material, leading to attacks on standing trees. Prompt removal of windthrown spruce and Douglas-fir in and near campgrounds is recommended. Ips prefer to attack fresh downed wood or logging slash (diameter > 2 in) or parts of damaged and severely weakened trees, including those attacked by other bark beetles. Populations of Ips can build up, causing attacks on apparently healthy trees. Twig beetles infest material smaller than 2-in diameter, and can kill small trees.

Mountain Pine Beetle

Mountain pine beetles and fire are the primary stand-replacement agents for pines in most of the Rocky Mountain Region. For lodgepole pine, susceptibility to mountain pine beetle is greatest for stands 80+ years of age, and with average DBH greater than 8 in (Figure 5). Treatments recommended to reduce susceptibility in lodgepole include: a) patch cuts to regenerate stands with high susceptibility, creating landscapes with low overall risk; b) partial cutting within stands to remove individual trees in the high-risk category (>8-in DBH); and c) partial cutting within stands to favor nonhost species. Thinning in lodgepole may enhance resistance to bark beetle attack by increasing tree vigor.

For ponderosa pine, risk of mountain pine beetle is highest for single storied stands with average DBH greater than 10 in and high stand density. Stand susceptibility can be lowered by thinning to basal areas less than 80 square feet per acre, and reducing average DBH. Multi-storied stands are less favorable for mountain pine beetle, but more favorable for spread and intensification of dwarf mistletoe if present.

Bark Beetle Control

When outbreak populations of beetles are expected to attack recreation sites, selected trees can be protected by applying insecticide before beetle flight every year during the outbreak. Managers should keep in mind that the commitment to the use of insecticide may be as long as 10 years depending on the severity of the epidemic. To prevent successful beetle attack, apply insecticide according to label directions.

Figure 5. Stand of mature lodgepole pines killed by mountain pine beetle in a campground in Colorado. Notice the dwarf mistletoe brooms in some of the dead pines.

Currently recommended insecticides include carbaryl (Sevin), permethrin (Astro), and bifenthrin (Onyx). Do not apply insecticides on windy days, to prevent drifting of insecticides to non-target species. Do not apply insecticides within 50 to 100 ft of a body of water or stream. Do not apply insecticides if rain is expected within 2 to 4 hours. Be careful not to contaminate water when cleaning equipment. Trees selected for spraying must be healthy. Consult your local entomologist for possible Forest Health funding and updated information on pesticide recommendations and registrations. The paper by Fettig and others (2008) might be useful when planning insecticide treatments near sensitive areas, such as open water.

For more information on bark beetles see the management guides posted on the Forest Health Protection website (Anonymous 2000).

SITE PLANNING

A high level of tree mortality affords an opportunity to initiate or reevaluate the vegetation management plan to make the best use of the physical and vegetative attributes of the site. The vegetation management planning process assists us in: 1) clearly defining resource management objectives in an integrated rather than additive manner; and 2) simultaneously considing a range of reasonable management options. Long-range plans are essential to achieving and maintaining any desired future condition. Build the plan using a map of the layout of the campground and surrounding forest, including water and electrical systems, drainage, and resource assets and liabilities. Involve the Forest Landscape Architect in the development of site plan objectives including screening, vegetative structure, amount of light, and location of signs and pathways.

Decide on the best access for placement or maintenance of pipelines and power corridors. Choose areas already compacted or with sparse vegetation. Maintain and repair infrastructure before the new forest is in place.

Design locations of desired screening and traffic patterns to make the best use of the potential for forest cover and screening (Figure 6). Where trees were standing between camp sites, the soil is usually not compacted. With some care, these areas can regenerate naturally and would be good areas to plan screening.

Figure 6. Young lodgepole pines providing screening between campsites in a campground in Colorado.

Vehicular traffic leaves soil severely compacted, while foot traffic causes compaction to a lesser extent. Compacted soils restrict root growth, and trees may not grow back in compacted soils. Where trees are desired and soils are compacted, a winged subsoiler can be used to successfully break up the compaction.

Within campsites, trees to provide future shade need to be located where their future size will not interfere with campers or vehicles. Campers need to be able to recognize the small trees and protect them. Educational notices on bulletin boards and signs near the regenerating forests can help educate recreationists. Interpretive panel signs might be placed at campground fee stations, explaining the revegetation efforts and showing pictures of tree seedlings. Online reservations could include an information packet.

For additional discussion on planning, please see Chapter 1 in the Vegetation Management Planning Guide (Anonymous 2003), and Chapter 2 and Appendix B in Harvey and Hessburg (1992).

CLEANUP AFTER TREE MORTALITY

Removing Dead Trees

The mountain pine beetle epidemic has left many dead and dying trees, and trees continue to be attacked. In the epidemic areas, the expectation is that few lodgepole pines greater than 6 inches diameter will remain alive when the epidemic finally subsides. Dead trees present an unacceptable hazard where people are camping overnight. Just removing the dead trees is likely to have to be repeated year after year, damaging the natural regeneration and postponing the new forest (Figure7).

Timber Sale

A better approach may be to re-evaluate the vegetation management plan, initiate regeneration of the lodgepole pine stand in which the campground is located, and maintain and repair infrastructure before the new forest is in place. A timber sale may be possible, or a stewardship contract that will reduce the costs of tree removal. It important to remember that cutting of dying or partially green trees is best done in the fall after bark beetles are done flying.

Firewood

Logs or log piles may be sold to local firewood operators, or left for free-use firewood gatherers. If logs are bucked up for camp firewood, make sure piles are not near living pines. Ips and twig beetles

Figure 7. Without an appropriate vegetation management plan, continual mortality from mountain pine beetle requires repeated tree removal in a campground in Colorado.

Figure 8. Pile of slash in sizes likely to be used by campers in a campground in Colorado.

are attracted to freshly cut green wood and may infest nearby standing pines.

Log Utilization

Logs are best limbed in place, where natural regeneration is desired. Logs and branches can then be placed to direct foot and vehicular traffic. Logs can be placed in streams and lakes for fish habitat. Various sizes of logs can be used to build buck & rail fencing to protect the new forest as it regenerates.

Whole-tree Yarding

Whole-tree yarding has the disadvantage of removing all material from the site, including cones and small branches. Removal of all slash removes the seed source, debris for microsite protection, and nutrients. However, the experience on some units has been that most of the cones fall off when red- and gray-needled trees are felled.

Slash Disposal

Down woody debris is beneficial for moisture retention to aid in seedling survival and wildlife habitat. Slash contains cones and protects the seedbed for the new forest. Fuel loading from slash is best kept to less than 20 tons per acre in vegetated areas, and slash needs to be pulled 15 ft away from structures and campsites.

Lop and Scatter

Smaller stems and branches, cut into lengths up to 30 inches and left scattered about will likely be utilized by campers. Small branches and cones are best scattered where natural regeneration is desired, making sure that slash is not too thick. Patches of bare soil should be visible through the slash. For fire concerns, Colorado State Forest Service recommends that landowners cut up and scatter slash, and spread it low to the ground, preferably no higher than 12 inches.

Piling

Where slash is too thick, stems and branches can be piled after cones have had a chance to open, usually at the end of the summer. Keep piles small and away from standing trees. Ips bark beetles are attracted to green slash piles and may infest nearby pines. Material that is small enough to handle will likely be used by campers (Figure 8). If desired, small piles can be burned in the fall after the first snow, when risk of fire spread is low.

Chipping or Grinding

Both chipping of slash and grinding of larger material generate large mounds of chips that need to be spread to dry quickly in order to avoid attracting Ips and twig beetles to nearby pines. Chips that are spread on the forest floor tend to ruin the seedbed for natural regeneration, because it is difficult to spread the chips thinly enough. The best places for chip placement are along foot paths and in campsites, especially to alleviate muddy conditions around picnic tables. Chips may be used as mulch around non-pine transplants.

NOXIOUS WEED PREVENTION

Noxious weeds are generally non-native plants that possess one or more of the following characteristics: aggressive and difficult to manage, poisonous, parasitic, a carrier or host of serious insects or disease, armored with spines, thorns, or burs. Each Forest has an Action Plan for prevention of the spread of

noxious weeds. The following points are excerpted from the Weed Prevention guide (Anonymous 2001).

Site Assessment

Inspect all campground sites, trailheads, and parking areas for noxious weeds. Before ground-disturbing activities begin, inventory and prioritize weed infestations for treatment in project operating areas and along access routes. Identify what weeds are on site, or within reasonably expected potential invasion vicinity. Treat new infestations and maintain in a weed-free condition.

Equipment Cleaning

On project area maps, show areas that are infested with specific noxious weed species of concern. Unless the entire project area is already infested, purchaser shall employ whatever cleaning methods are necessary to ensure that off-road equipment is free of noxious weeds prior to moving onto the project area. All off-road equipment, which last operated in areas known by the Forest Service to be infested with specific noxious weeds of concern, must be free of soil, seeds, vegetative matter, or other debris that could contain or hold seeds.

The purchaser shall certify in writing that off-road equipment is free of noxious weeds prior to each start-up of timber sale operations and for subsequent moves. Equipment shall be considered free of soil, seeds, and other such debris when a visual inspection does not disclose such material. Disassembly of equipment components or specialized inspection tools is not required.

Preventive Procedures

Avoid or remove sources of weed seed and propagules to prevent new weed infestations and the spread of existing weeds. To reduce risk of spreading weed infestations, begin project operations in uninfested areas before operating in weed-infested areas. Locate and use weed-free project staging areas. Avoid or minimize all types of travel through weed-infested areas, or restrict to those periods when spread of seed or propagules is least likely.

Limit vehicles to designated, maintained travel routes. Inspect and document inspections on travelways for weeds and treat as necessary. Ensure that rental equipment is free of weed seed and propagules before the contracting officer's representative accepts it.

WHAT TO PLANT

Determining what species to plant depends on what species can grow on the site, the desired function of the plant, and insect and disease susceptibilities of available species.

What Will Grow

Look for species of trees and shrubs growing in and near the campground. It is likely that the species that are already present will grow most successfully. Slight differences in microsite environments can determine whether some species can survive. Observe what kinds of environments species are growing in, and seek similar microsites for planting (Figure 9). Seedlings in general often need some amount of shade during the hottest part of the summer day in order to survive. Spruce seedlings need more moisture than pines and almost full shade for their crowns and lower stems.

Desired Functions

Screening

For the function of screening between campsites, possibilities include many shrubs and most species of trees while young. Saplings of all conifers tend to have foliage over their entire height. Shade intolerant species such as pines begin to shed shaded branches as their crowns close. In areas some distance from the campsites, fast-growing species such as aspen and cottonwoods can provide excellent screening, keeping in mind that they are very susceptible to disease and quickly become hazardous when mature.

Tree Component

For the desired tree component to provide shade and forested appearance, the best species are pines followed by spruces and Douglas-fir on sites that can sustain them. Some time is required while the new forest grows to full tree size.

Figure 9. Spruce sapling naturally regenerated in slight swale in a campground in Colorado.

Ground cover

Where traffic is avoided, native forbs, grasses, and shrubs tend to resprout or seed in themselves. Downed trees and large pieces of slash can be placed to direct foot traffic and protect some areas for vegetation recovery. Where slash is chipped, chips are best placed in high traffic areas, such as footpaths and the campsites themselves, and not the forest floor. A layer of chips can help ameliorate muddy conditions around picnic tables.

Insect and Disease Susceptibilities

Pines

Pines, including ponderosa, lodgepole, bristlecone, whitebark, limber, and pinyon, are the best trees for campgrounds because they are the most tolerant of camper abuse. Pines are relatively resistant to decay and diseases, except for dwarf mistletoes. Heavy infections of dwarf mistletoe lead to crown decline and tree mortality. Dwarf mistletoe in the overstory will prevent understory pines (within 50 ft) from growing into tall trees. Advanced regeneration growing under a dwarf-mistletoe-infested overstory will likely be infested, even though aerial shoots and brooms are not yet apparent. Both ponderosa and lodgepole pines may have western gall rust, which can deform stems and girdle small-diameter branches. Bark beetle susceptibilities are slightly different among the pines.

Lodgepole Pine is tolerant of poor soils. A predominance of lodgepole pine may indicate that lodgepole pine grows best on the site. The soil may be too cold and dry, or the site may be in a frost pocket, where few other species can thrive. Other sites with predominantly lodgepole pine may be seral, with appreciable numbers of more shade-tolerant species in the understory, *i.e*, Douglas-fir, Engelmann spruce or true fir (See Figures 1 and 5). On these kinds of sites, the shade-tolerant species will eventually dominate. Where many trees have fallen or been cut, remaining live lodgepole pines often blow down.

Lodgepole pine is relatively short-lived, becoming susceptible to mountain pine beetle when the stand is over 80 years old. Although mountain pine beetle typically attacks lodgepole pine in stands with average diameter of 8 in or greater, under current outbreak conditions, few lodgepole pine stems over 6-in diameter are expected to escape lethal attack. Populations of pine engraver beetles (*Ips* spp) have also built up and are killing stems, tops and branches larger than 2-in diameter. Populations of twig beetles have also built up and are infesting smaller material. In many places, lodgepole pine must be completely regenerated, because the advanced regeneration is infested with dwarf mistletoe.

Lodgepole pine (*Pinus contorta* ssp *latifolia*) usually has serotinous cones that remain closed until exposed to high temperatures generated by full sunlight or fire. This characteristic allows lodgepole pine to regenerate naturally from logging slash, given bare mineral soil, closed cones in the slash, sunlight, and moisture. Usually enough bare mineral soil will be exposed during the logging operation, as long as the slash is not too thick. In some situations where ground and seed conditions are not conducive to natural regeneration, lodgepole pine is planted after harvest.

Ponderosa pine can live for hundreds of years providing stand density is low, soil is not compacted, and dwarf mistletoe is absent or only reaches light infection levels.

For ponderosa pine, stand density and moisture relations determine susceptibility to mountain pine beetle. Consult your Forest Health entomologist (Lakewood Service Center, 303-236-9552; Gunnison Service Center, 970-642-1144; Rapid City Service Center, 605-716-2797) for stand risk-rating. Under current outbreak levels of mountain pine beetle, mortality is expected in ponderosa pine under stress due to soil compaction or high stand density. The build-up of Ips may cause mortality of small-diameter stems and tops.

Ponderosa pine regenerates naturally in a seed-tree or shelterwood environment, requiring an overstory seed source, bare mineral soil, adequate moisture, and a good cone crop. Ponderosa pine is often planted to speed up regeneration.

Five-needle pines are good species for recreation sites, where they occur at higher elevations. Limber, bristlecone, and whitebark pines grow slowly and are long-lived. Serious diseases include dwarf mistletoes and white pine blister rust, which causes girdling cankers on branches and boles. They are also susceptible to mountain pine beetle.

Pinyon pine and Rocky Mountain juniper are also good for campgrounds. They are slow-growing and usually resistant to many insects and diseases. After multiple years of drought, pinyon pine may succumb to outbreaks of Ips beetles.

Spruces and Douglas-fir

Spruces and Douglas-fir are the next best trees for campgrounds, after the pines. Both can live for hundreds of years in the absence of soil compaction and bark beetle attack.

Spruces have relatively prickly foliage and can be placed to control foot traffic. Spruces tend to keep their lower branches, maintaining screening properties longer than pines. Older spruces tend to have root and butt rot that often leads to lower-stem failures and blowdown. This is less frequent in Douglas-fir.

Under outbreak conditions of mountain pine beetle, spruces in stands mixed with lodgepole pine are sometimes attacked and killed. Spruce beetle outbreaks are usually initiated where large numbers of spruce have been blown down; significant mortality of standing Engelmann spruce may result from these outbreaks. Spruces are fairly slow to regenerate under shelterwood conditions, and are often planted after harvest to augment natural regeneration. Spruce seedlings need almost full shade and moist microsites.

Douglas-firs are more susceptible to root disease than pines are, and young trees have relatively thin bark. Older Douglas-firs tend to have root and butt rot that can lead to lower-stem failures, but less than in spruces. Douglas-fir dwarf mistletoe causes formation of very large brooms that reduce tree vigor and can lead to mortality. Dwarf mistletoe in the overstory will prevent understory Douglas-fir (within 50 ft of infected tree) from growing into tall trees.

Douglas-fir beetle and sometimes the Douglas-fir engraver can cause mortality in Douglas-firs stressed by diseases or defoliation, which are often exacerbated by soil compaction. Douglas-firs are commonly defoliated during outbreaks of western spruce budworm or Douglas-fir tussock moth.

Douglas-firs are fairly slow to regenerate under shelterwood conditions, and are often planted after harvest to augment natural regeneration. Shading of the lower stem is important for seedling survival.

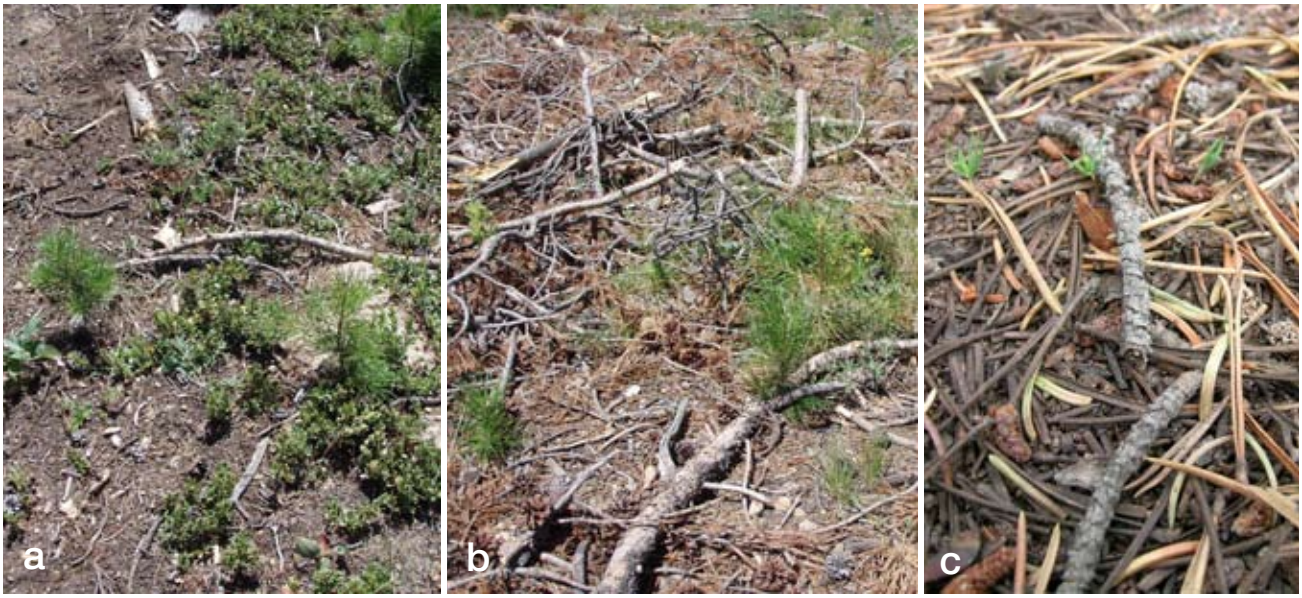

Figure 10. Sufficient small slash and cones, as well as bare mineral soil, were left after tree removal to facilitate natural regeneration of lodgepole pine. Seedlings are a few years old (a and b); newly germinated conifer seedlings coming up through light duff (c), in campgrounds in Colorado.

Figure 11. Slash left too thick for conifer seedlings to penetrate in campgrounds in Colorado. No bare mineral soil is evident.

True firs and Hardwoods

True firs and cottonwoods, aspens, and other hardwoods, are best used only for screening and a tree component some distance from campsites.

True firs are not a good choice for planting or transplanting. True firs have thin bark, especially when they are young, and grow slowly. True firs are more susceptible to root diseases and stem decays than other conifers. Dwarf mistletoe and broom rust infections on the main stem are entry points for decay fungi, increasing the risk of stem failure. When root disease is present or during times of drought or other stresses, white and subalpine firs are often killed by fir engraver or western balsam bark beetles. Because of these susceptibilities, true firs tend to be

short-lived in recreation settings, and are best used as a screening or tree component some distance away from camp sites.

Cottonwoods are fast growing in moist environments and short lived in recreation settings. Cottonwoods are susceptible to stem, root and butt rot. Large branches are prone to decay that is difficult to detect. Mature cottonwoods are usually hazardous and should be replaced before they are 70 years old. Cottonwoods regenerate readily from stump sprouts and from seed where their 'cotton' accumulates in moist areas.

Aspens are not a good choice for planting or transplanting. Aspens are short-lived in recreation settings due to thin bark and susceptibility to camper abuse. The thin bark is easily damaged, and even small wounds are readily infected by canker diseases and stem decays. Root decays cause mature aspens to topple. Aspens sprout readily from roots, and small aspens are often root sprouts that rely on a large underground network of roots connected to larger aspen trees. Aspens are usually seral where they occur with conifers. In recreation sites with a large component of aspens, conifers should be planted near and among the aspens, as replacement trees, as directed in FSM Supplement (R2) 2333.48-93-6.

SOURCES OF PLANTS

Sources of plants for revegetation of campgrounds include natural regeneration, planting seedlings grown at Bessey Nursery, and transplanting shrubs and small trees from nearby forests. All seeds and seedlings need to come from within the same seed zone as the campground. The Plant Materials Centers operated by Natural Resources Conservation Service (NRCS) might be another option for growing appropriate stock.

Natural Regeneration of Lodgepole Pine

Given adequate site preparation, lodgepole pine can reseed itself naturally. Requirements include closed brown cones on the ground, bare mineral soil, uncompacted soil, and protection from trampling and excessive heat. Usually enough bare soil is exposed during the logging operations. A thin layer of slash on the ground affords an abundance of suitable microsites for seedling establishment. Bare mineral soil should be visible in patches through the slash (Figures 10 and 11).

Leave small branches and cones on mineral soil in areas protected from traffic. Because of hot, dry summer weather, and high temperatures of the soil surface, shaded microsites are important for survival of tree seedlings. Small branches scattered over the regeneration site afford shade, as well as cushioning from trampling. Even a small stump left 12 in high can provide a bit of afternoon shade for a struggling seedling.

Seedlings will come up in clumps over the next couple of years. They may need thinning and physical protection from trampling. Areas of natural regeneration could be flagged off and signs posted, encouraging campers to avoid trampling seedlings.

Planting Seedlings from Bessey Nursery

Use only locally-adapted seed sources. Do not acquire stock from nearby horticultural businesses. Plants that are not locally adapted may become established and grow well initially, but die or grow poorly when they become infected with a disease or experience climatic extremes (such as drought or early frost). Both the geographic area and the elevation band are important when determining whether seed is locally adapted.

In order to grow appropriate stock at Bessey Nursery, several steps must be completed. District silviculturists and foresters have the knowledge and experience to ensure that each step is completed in a timely and efficient manner. This section presents points to consider as background information for recreation personnel to collaborate with forestry personnel.

Successful regeneration efforts require a series of actions correctly completed, from collecting cones through maintaining a plantation. Failure can result from a single major event or an accumulation of small events when managers do not attend to basic reforestation principles. The tolerance of seedlings

for improper care outside their natural environment is very limited. Improper care may cause stress, injury, or mortality.

Before planting, steps may include cone collection, sowing orders, seedling storage and handling, and site preparation. During planting, considerations include microsite selection, planting techniques, and planting tools.

Cone collection

Seed is stored at Bessey Nursery seed bank, and a listing of the seed inventory for each District can be obtained by contacting Bessey Nursery or checking the nursery web page: http://www.fs.fed.us/r2/nebraska/contact/charles_e_bessey/nursery.shtml. Cone collection is necessary unless a sufficient quantity of the appropriate seedlot is in storage at Bessey. Cones are collected late in the summer and shipped to Bessey for processing. Cones should be green and unopened. Serotinous lodgepole pine cones can be brown and unopened. Refer to the cone handbook for proper cone collection. Cone bags and tags can be obtained by contacting Bessey Nursery Manager (Richard Gilbert at regilbert@fs.fed.us, 308-533-2257, ext 8117).

Sowing Orders

Sowing orders include how many seedlings and what sizes are desirable and feasible. Different kinds of stock entail different time frames and costs. Any **plug**+ transplant stock needs to be ordered a year before seed is expected to be sown. Plugs are grown in the greenhouse in two possible crop cycles, and space is limited in the greenhouse. Planning ahead provides for more efficient use of time and space; otherwise orders end up being first come first served.

Table 1. Approximate stock sizes and 2008 prices for stock grown by Bessey Nursery.

Lodgepole Pine

Stock	Caliper (mm)	Height (in)	Cost $/1000	Growing Time after Sowing
2+0 bareroot	6	12	550	2 years
Plug+1	5	8	720	1 year
Plug+2	8	16	1400	2-3 years
1+1 Container	8	14	3850	2 years

Ponderosa Pine

Stock	Caliper (mm)	Height (in)	Cost $/1000	Growing Time after Sowing
2+0 bareroot	6	10	550	2 years
Plug+1	5	5	720	1 year
Plug+2	8	14	1400	2-3 years
1+1 Container	8	10	3850	2 years

Engelmann Spruce

Stock	Caliper (mm)	Height (in)	Cost $/1000	Growing Time after Sowing
Plug+1	5	6	720	1 year
Plug+2	8	12-15	1400	2-3 years
1+1 Container	8	12	3850	2 years

Transplants into larger containers are grown in shade frames and do not need further greenhouse space.

Bessey Nursery can grow a number of different sizes of conifers and shrubs, tailored to the needs of the customer. Conventional designations for nursery stock are based on bareroot seedlings grown in the nursery beds (soil) for a number of seasons plus (+) an additional number of seasons after seedlings are transplanted back into nursery beds at wider spacing. Thus, 2+0 stock is sown in nursery beds in spring and grown for **two** summers in place, then lifted in fall and stored for outplanting at the field site the following spring (zero growing seasons after transplanting). **1+1** stock would be sown into nursery beds in the spring, grown for one summer, then transplanted back into nursery beds at wider spacing and grown for an additional summer.

Seedlings grown in the greenhouse are container stock, and are designated by the words 'plug' or 'container.' **Plug+1** stock is started in small containers in the greenhouse in the winter and transplanted to nursery beds to grow for the summer, then lifted in the fall. Another stock type proposed for lodgepole and ponderosa pines is the **plug+2**, which would grow for two summers after transplanting into nursery beds. **1+1 container** stock is started in small containers in the greenhouse in the winter and transplanted to larger containers to grow a second summer in a shade frame. Container stock can be hardened off for storage, shipment, and outplanting with more flexibility than can stock lifted from the nursery beds. The advantages of a transplanted seedling are a more robust root system, larger caliper, and acclimation to outside conditions.

Plug+1 stock can be started in two different sizes of containers and take one year to produce. Many customers consider the **plug+1** seedling to be better than seedlings grown in nursery beds for two years (2+0 bare-root). **Plug+2** may be the best regime for lodgepole and ponderosa pines, but customers have yet to order any. Table 1 compares stock sizes and prices in general for lodgepole and ponderosa pines and Engelmann spruce to give an indication of the relative differences in price and product. Different seedlots within a species may have very different growth, and costs vary continually due to fluctuating prices for fertilizer and other supplies.

Examples of Recent Sowing Orders

In recent years, Forest needs have led to larger material (seedlings) being grown in a variety of ways. For recreation sites on White River NF, the target seedling (having desired morphology at time of lifting) will be 3 to 5 ft tall with a root mass 12-in diameter and 12 to 15 in deep, which will take 4 to 5 years. Lodgepole and ponderosa pines, Engelmann spruce, and Douglas-fir seed was sown in size 160 plugs in early 2007, and seedlings were transplanted in spring 2008. Ponderosa pine was transplanted into 'grow-bags' in the nursery beds, and the other three species into larger containers in shade frames. By the end of July 2008, the lodgepole pine and Engelmann spruce had calipers of almost 8 mm and all three container species had heights approximately 12 in, after a year and a half since sowing. All of the species would do well planted in spring 2009 (**1+1 container** stock). Seedlings held to grow larger will be transplanted to 'grow-bags' in the nursery beds (pine) or to large, open-bottomed containers and grown in shade frames (Douglas-fir and Engelmann spruce). Either regime would allow seedlings to be held for more years without detriment, except they would grow larger. Transportation and planting logistics have yet to be determined, and grow bags must be cut away from planted seedlings. Districts might use a bobcat or backhoe with a bucket or large soil auger to dig planting holes and plant the seedlings. Estimated cost of the seedlings held 4 to 5 years is $22 to $30 each.

For recreation sites on Medicine Bow/Routt NF, target seedlings will be approximately 2 ft tall with lateral branches. Sowing of Engelmann spruce and lodgepole pine is scheduled for January 2009, beginning in small 240 plugs, and transplanted in May 2010. Stock to be planted in spring 2011 (**1+1 container**) will be transplanted into 42 cubic-in containers, and cost will be approximately $4 each. Larger stock to be planted later will be transplanted into ¾-gallon (171-cu in) containers with open bottoms. Stock grown until 2012 (**1+2 container**) will cost approximately $8 each, and those grown until 2013 (**1+3 container**) will cost approximately

$12 each. Lodgepole pine will grow faster than the spruce. Seedlings could be held for 1 to 2 extra years without detriment.

Seedling Storage and Handling

Seedlings must be stored in dormant condition until planting. Dormancy is a resting stage during which tissues will not grow because of internal inhibitions. During relatively deep dormancy, seedlings have as much resistance to environmental stress as possible. Trees that have broken dormancy will deteriorate rapidly in storage, even under the best conditions. Storage facilities must have the insulation, cooling capacity, and air circulation needed to maintain 95+ percent relative humidity and a constant 33 to 34°F temperature within the seedling package for unfrozen stock and a temperature of 26 to 28°F for frozen stock. Frozen storage and frozen shipping is best. Thawed seedlings have only about 3 weeks shelf-life, held at 33 to 34°F.

Figure 12. Cleared planting spot.
(Photo from http//www.forestryimages.org)

Handle with care. Even limited rough handling can reduce survival. In most instances the seedlings will show no indication of the damage because the damage is most likely to occur at the cellular level. Although the effects of rough handling can be more pronounced in some species than others, make every effort not to drop, slam, or otherwise disturb the seedling containers. When handling seedlings, keep roots covered as much as possible to retain moisture and limit light.

Timing of Planting

Planting must be timed to take advantage of good soil moisture conditions. Normally, early morning frosts do not damage seedlings right after planting, but extended cold temperatures in the lower teens and twenties cause problems. Wind can make the problems worse. Do not plant seedlings during freezing temperatures and do not expose their roots to freezing temperatures during planting. Favorable soil temperature for planting is around 50°F. Favorable air temperatures for planting are 33 to 55°F.

For spring planting, wait until after snowmelt and after the last killing frost, when soils are no longer water-logged. Bare-root seedlings are planted only during the spring.

For fall planting of container stock, be sure soil is moist. Seedlings planted from mid-August through September are able to harden off normally as days shorten and night temperatures fall. By mid-October, these seedlings become cold hardy and can withstand temperatures well below freezing.

Preparing the Planting Site

In a typical planting sequence, personnel select microsites to take advantage of natural shelter and favorable soil conditions. Various implements are used to remove ground cover and to prepare a suitable hole for the seedling. The seedling is carefully placed in the hole and soil is packed around its roots. In dry areas, a moisture-catch basin should be constructed. Forest litter of various sizes may be placed around the planting spot to help retain moisture.

Shading

Choose or create a microsite with partial shade. Shade materials may be natural, including dead plants, slash, and even rocks. Artificial shade should not be necessary where sufficient slash was retained after dead tree removal. Planting in favorable microsites protects seedlings from potentially harmful conditions and improves the probability they will survive. This is especially true in areas of high animal use, strong sunlight, and winds.

Keep in mind that living plants can compete with seedlings for moisture, so it is best not to rely on live plants for shading. However, where living plants provide shade, select planting spots that minimize moisture competition and protect seedlings from afternoon sun. Plant near the root crown of shrubs because water-absorbing roots of shrubs are denser farther away from the root crown, and seedlings will be more protected from browsing animals. Plant outside the dripline of healthy trees, and within the shade pattern of the afternoon sun. If existing trees have dwarf mistletoe, do not plant seedlings of the same species within 50 ft from mature trees, or 30 ft from small trees with infections less than 15 ft high. Grasses are highly competitive with seedlings for soil moisture, so planting on grassy sites should be avoided. When planting in grassy sites is necessary, scalp the planting site in the manner described below under "Scalping".

Plant seedlings on the north and northeast sides of larger debris, but do not let large rocks touch a seedling. Slash is ideal for microsites and can be moved to afford the best shade. Place smaller material to shade the ground and the base of the seedling from the afternoon sun. Stumps left at least 12 in high afford shade during summer afternoons. Tall stumps are less easily tripped over, and are likely to be stepped on, thus protecting the nearby seedlings. Plant seedlings near stumps, unless Armillaria root disease is a known problem in the area.

Clearing

Clearing keeps debris from entering the planting hole. Remove all surface debris down to moist mineral soil within an area of at least 6-in diameter. Remove duff, litter, rotten or charred wood, loose rock, ashes, snow, surface frost, and similar debris (Figure 12). After the tree has been planted, this material is best pushed back over the cleared surface to serve as mulch. Do not let mulch touch the main stem (trunk) of the seedling.

Scalping

Scalping delays competition from surrounding plants. Cut and remove all vegetation to at least 1½ in below the vegetation's root crown. The width of the scalp depends on the amount and kind of competing vegetation. Planting in sod-forming grasses generally requires a scalp that is 18 to 24 in wide. If larger scalps are needed, consider using herbicide and mechanical spot treatments.

Planting

Planting could be accomplished through partnerships with volunteer groups, such as Boy Scouts of America. Planting holes could be made with an auger ahead of time, and volunteers need to be shown proper planting technique. Many plantation failures can be attributed to poor training of volunteers.

The Planting Hole

Locate holes for tree planting in good soil that is deep enough to accommodate the seedling's roots when they are fully extended. Seedlings should not be planted in rotten logs, duff, mixes of organic matter, or soil that easily dries out. The hole must

Figure 13. Cluster of young lodgepole pine that would be a good source of transplants, provided the dwarf mistletoe-infected overstory was at least 50 ft away, in a campground in Colorado.

be large enough in all dimensions so that the seedling's roots may be inserted without being deformed or damaged. All roots should be planted so they are vertical, with the exception of an occasional long lateral root that can be laid in the bottom of the hole.

Use the Open Hole Method when planting. Use the planting tool to open a hole large enough to allow for the tree roots to be aligned naturally and soil to be compacted. Place the seedling's roots into the hole; place loosened soil back into the hole and pro-

Figure 14. Problems with transplanting include insufficient soil moisture (a) and planting too shallow (b). Sapling with exposed root (b) showed very stunted growth and may succumb to Ips beetles or drought, in a campground in Colorado.

gressively firm the soil from the bottom of the hole toward the top. The seedling should be positioned in the center of the hole. Do not tamp the soil with sticks or by heeling in the soil alongside the seedlings after they have been planted. Do not leave any air pockets or debris in the hole. Roots that are not in close contact with mineral soil will dry, killing the seedling. In dry areas, a moisture-catch basin should be constructed.

Planting Depth

Plant the seedling at about the same ground line as established at the nursery. The root collar or cotyledon scar is an indicator of the original ground line. No portion of the roots should be exposed, nor should any needles or branches be covered with soil. Correct depth placement is especially critical on sites with high insolation. The stem tissue at the base of the seedling is thicker and provides better insulation than stem tissue above the ground line or root tissue below. High soil temperatures at the ground line can be lethal to tender stem or root tissue. For container stock in areas subject to frost heaving, plant the root plug deep enough so that about 1 inch of soil can be placed on top of the root plug, level with the surrounding soil surface. In all cases, the entire root plug and rooting medium must be below the ground surface. (Seedlings are never planted while still in containers.)

Supplemental Care

Water in the planted seedlings, and then water well every couple of weeks until precipitation is adequate. Campers could be encouraged to water seedlings near their campsites during summer dry spells. Consider protecting planted pines from Ips and twig beetles by applying preventive insecticide to the bark. To prevent successful beetle attack, apply insecticide according to label directions. Recommended insecticides include carbaryl (Sevin), permethrin (Astro), and bifenthrin (Onyx). Check with your local Forest Health entomologist for up-to-date pesticide recommendations. Do not apply insecticides on windy days, to prevent drifting of insecticides to non-target species. Do not apply insecticides within 50 to 100 ft of to a body of water or stream. Do not apply insecticides if rain is expected within 2 to 4 hours. Be careful not to contaminate water when cleaning equipment.

Stocking

For shade intolerant species such as pines, the longer a tree can grow without contacting or being shaded by the crown of a neighboring tree, the longer and

fuller its crown will be. When their crowns touch, pines begin to shed lower shaded branches. Desired future condition for pines in a recreation setting would be an open stand of low density, with basal area less than 80 sq ft/acre.

Transplanting from Nearby Forests

Transplant small trees and shrubs from nearby forests at the same elevation and with similar environmental conditions. Do not acquire stock from horticultural businesses. Plants that are not locally adapted may become established and grow well initially, but die or grow poorly when they become infected with a disease or experience climatic extremes (such as drought or early frost). Transplanting should only be attempted in the spring or fall when soil moisture is adequate, and tree roots have some propensity for growth. Transplanting is a labor-intensive process and may require special equipment. Additional hand shoveling is necessary to firm the planting-site soil around the transplanted root wad. Transplanted trees need to be watered in, and then watered well every couple of weeks until precipitation is adequate.

Selection

Select only **healthy trees** for transplanting (Figure 13). Inspect pines for rust cankers and for swellings from western gall rust and dwarf mistletoe. Do not use pines or Douglas-fir growing under an overstory of the same species that is infected with dwarf mistletoe, because the understory is probably infected, although infections may not be apparent yet. These latent infections often produce aerial shoots when the branches are exposed to more light.

Clearing

Clearing keeps debris from entering the planting hole. Remove all surface debris down to moist mineral soil within an area of at least 6-in diameter. Remove duff, litter, rotten or charred wood, loose rock, ashes, snow, surface frost, and similar debris (see Figure 12). After the tree has been transplanted, this material is best pushed back over the cleared surface to serve as mulch. Do not push mulch up against the trunk of the tree. It can provide habitat for rodents that may girdle the trunk.

Scalping

Scalping delays competition from surrounding plants. Cut and remove all vegetation to at least 1½ in below the vegetation's root crown. The width of the scalp depends on the amount and kind of competing vegetation. Planting in sod-forming grasses generally requires scalp that is 18 to 24-in wide. If larger scalps are needed, consider using herbicide and mechanical spot treatments.

Equipment

Choose the right size of equipment; plan to dig up and transfer at least one third to one half the volume of root wad as the above-ground portion of the tree. Some forests have purchased truck-mounted or bobcat-mounted tree spades. Equipment can also be rented.

In the ideal situation when the soil does not contain large rocks, a star tree spade can be used to make the planting hole, and then to dig up and transplant the tree, with the least disturbance to its roots. After planting, pack the soil around the root wad.

When a star tree spade is not available, a truncated tree spade may be used when soil moisture is adequate to hold the root wad. Place the root wad in burlap supported by a large wire-mesh basket for transport. After inserting the basket containing the root wad into the planting hole, snip away the wire basket. If the basket is left intact, severe root constriction may occur in the future. Where the planting soil is too rocky, a backhoe can be used to dig a planting hole deep enough. Then hand shoveling is needed to shape the hole to fit the root wad.

When a tree spade is not available, some success may be achieved using a bucket-excavator to both dig the hole, dig up the tree, transport it, and insert it into the planting hole. Hand shoveling is necessary to fit the planting hole to the root wad.

For very small trees and shrubs transplanted from within a few hundred feet, hand shovels can be used to dig up, carefully transport, and plant them.

Placement and Care

Plant outside the dripline of healthy trees. If existing trees have dwarf mistletoe, do not plant seedlings of

the same species within 50 ft from mature trees, or 30 ft from small trees with infections less than 15 ft high.

Plant small trees at about the same ground line as in their original location. The root collar or cotyledon scar is an indicator of the original ground line. No portion of the roots should be exposed, nor should any needles or branches be covered with soil (Figure 14b).

Keep the sunny side out to prevent sunscald of previously shaded bark. Place transplants in the same orientation to the sun as in their original site. Make note of the cardinal directions of the tree in its original location, and transplant it using the same orientation.

All transplanted stock require supplemental watering until the root system is established. Trees transplanted in the spring may need watering at least every two weeks until summer rains set in (Figure 14a). In dry areas, a moisture-catch basin should be constructed, with the tree near the bottom of the basin. Forest litter may be placed around the planting spot as mulch to help retain moisture.

Select appropriate sites and microsites. Spruces need more cool and moist sites than pines do. Choose swales and heavily shaded microsites for spruces.

Protection

Protect transplanted pines from bark beetles. The stress of transplanting will leave pines very attractive to pine engravers (*Ips* spp) and twig beetles. To prevent successful beetle attack, apply insecticide according to label directions. Suggested insecticides include carbaryl (Sevin), permethrin (Astro), and bifenthrin (Onyx). Do not apply insecticides on windy days, to prevent drifting of insecticides to non-target species. Do not apply insecticides within 50 to 100 ft of a body of water or stream. Do not apply insecticides if rain is expected within 2 to 4 hours. Be careful not to contaminate water when cleaning equipment.

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Photography

All photos taken by Diane Hildebrand for U.S. Forest Service, Rocky Mountain Region, except as noted in caption.

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